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FOR

SYSTEM AND METHOD FOR CALIBRATING A HARD DISC DRIVE MAGNETIC HEAD FLYING HEIGHT TESTER BY OPTICAL INTERFERENCE TECHNIQUES

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SYSTEM AND METHOD FOR CALIBRATING A HARD DISC DRIVE MAGNETIC HEAD FLYING HEIGHT TESTER BY OPTICAL INTERFERENCE TECHNIQUES

Background Information

[0001] The present invention relates to optical gap measuring tool calibration. More specifically, the invention relates to a system and method for calibrating a hard disc drive magnetic head flying height tester by optical interference techniques.

[0002] **Figure 1** provides an illustration of a typical hard disc drive. In the art of hard disc drives, magnetic read/write heads 102 are commonly integrated in a slider 102 designed to respond to a flow of air moving with the rotating disc 104 over which the slider 102 travels. The head/slider 102 'flies' close to the surface of the disc 104. In manufacturing such heads/sliders 102, it is often necessary to test hydrodynamic characteristics of the heads 102 to verify their performance. It is important that the head 102 not travel too far from or close to the disc 104 surface. Further, it is important to prevent the head 102 from traveling at an improper angle with respect to the disc surface 104. A head 102 traveling too high above the disc surface 104 will result in a lower than desired areal density. A head 102 traveling too low can cause an interface failure between the head 102 and disc 104.

[0003] In order to test the flying height of the head, a flying height tester is commonly used. Optical interference techniques are often employed to determine the distance between head and disc. A monochromatic light source is directed at a transparent surrogate disc, such as a glass disc, rotating at speeds similar to that of a magnetic disc, and the head assembly being tested is secured in a holder in its normal flying orientation in relation to the disc. The monochromatic light is directed at the disc at a predetermined angle to the surface thereof. The

light is reflected from the surface of the disc closest to the head, as well as from the surface of the flying head itself, and impinges onto a light sensitive sensor.

[0004] The interference effects created by the combined reflections from the disc and the slider surface provide the flying height information. A computer receives data from the flying height tester and calculates the perceived flying height and angle of the head. As hard drives become smaller and increase in data storage capacity, the desired head flying height continually reduces. Therefore, the accuracy of a flying height tester, and thus its calibration, are of critical concern.

[0005] **Figure 2** illustrates a typical device used to calibrate a flying height tester. A calibration standard, such as is depicted in U.S. Patent Number 5,552,884, is often utilized. As can be seen in **Figure 2a**, the calibration standard includes a mock head 48 in contact with a transparent disc 44 via a load spring 52. The transparent disc 44 has a plurality of grooves 60 formed in a surface facing the mock head 48. A cover case 56 is attached to the glass disc 44 at one end and provides a sealed environment for the interface between the mock head 48 assembly and the transparent disc 44. Several problems exist with the utilization of this device. For example, in establishing H1 204, which is important in evaluating flying height (explained below), the nature of the design causes problems with using optical interference means. Measurement of H1 205 must not be taken too close to a ridge's 64 edge, or else one (or both) of the measurement light beam's return paths 206,208 may travel a portion through air (separated by the walls at 120 and 124). The differences in optical properties between air and the transparent disc (glass, etc.) disrupts the travel path and thus causes inaccurate optical interference measurement results (*i.e.*, the resultant beams 206 and 208 are not at the correct positions and/or the correct distance apart for accurate measurement). Therefore, H1

measurements may only be taken towards the center of the ridges 64 (if at all). This prevents appropriate compensation for surface irregularities 76 in the mock disc 48. Also, a separate device must be used to determine a minimum and maximum light intensity for the flying height tester, a necessary step in calibration, as explained below. This separate device adds cost and complexity to the calibration process.

[0006] It is therefore desirable to have a system and method for calibrating flying height testers that avoids the above-mentioned problems, as well as having additional benefits.

Brief Description Of The Drawings

[0007] **Figure 1** provides an illustration of a typical hard disc drive.

[0008] **Figure 2** illustrates a typical device used to calibrate a flying height tester.

[0009] **Figure 3** illustrates a flying height tester calibration standard according to an embodiment of the present invention.

[0010] **Figure 4** illustrates surface irregularity compensation and provides further detailed illustrations of two mock heads according to an embodiment of the present invention.

[0011] **Figure 5** provides a graphical illustration of the 'unique fit' solution utilized for providing a continuous spectrum of uniquely-valued combinations associatable to a range of head/disc gaps under principles of an embodiment of the present invention.

[0012] **Figure 6** provides an illustration of a mock head design according to an alternative embodiment of the present invention.

[0013] **Figure 7** provides illustrations of three mock head designs according to alternative embodiments of the present invention.

Detailed Description

[0014] **Figure 3** illustrates a flying height tester calibration standard according to an embodiment of the present invention. As can be seen in **Figure 3a**, in one embodiment, the calibration standard 100 includes a transparent mock disc 10 and one or more mock heads 20 placed in substantial contact with the mock disc 10 by one or more load springs 40. In this embodiment, a cover 50 is utilized to protect the standard from contaminants such as dust and debris. In this embodiment, two screws 71,72 are used to secure the cover 50 (and thus, the mock heads 20) to the mock disc 10. In this embodiment, the mock disc 10 is made of a substantially smooth, transparent material such as glass. Further, in this embodiment, the mock head 20 is provided an overcoat by thin film chemical deposition to emulate the optical properties of a head/slider.

[0015] In one embodiment, the height standard 100 plays two roles: a light intensity calibration tool and a height calibration tool. As a light intensity calibration tool, an inclined surface 22 on one or more of the mock heads 20 is utilized. As shown in **Figure 3b**, in one embodiment, the light source 80 of the flying height tester is moved (with respect to the standard) along the inclined surface 22. As the tester is passed over the inclined surface 22, optical interference techniques (described below) yield an oscillating, continuous spectrum containing segments of high intensity light as well as darker segments. From this continuous spectrum, values for both maximum light intensity and minimum light intensity received at the detector 90 can be established. In this embodiment, the values of light intensity are stored in a computer (not shown) associated to the flying height tester.

[0016] After establishing the range of light intensity for the flying height tester, in an embodiment, the depth (flying height) of at least one surface recess 302 is measured with the flying height tester to determine at least one 'observed' distance between the disc 10 and surface 23 of recessed portion 302. In this embodiment, the physical dimensions of the mock head 20 may be determined by a device, such as an atomic force microscope (AFM), and thus, the 'actual' distance between the disc 10 and the surface 23 of the recessed portion 302 can be compared to the 'observed' distance for calibration of the flying height tester. The differential between 'actual' and 'observed' distance is used to adjust the flying height tester for calibration. In one embodiment, multiple recessed portions 302 of differing depths (heights) are provided to improve calibration (calibration for different heights). Also, because the dimensions of the inclined surface 22 are known, it can be used to perform gap calibration as well (*i.e.*, depth being known at any position x).

[0017] As explained, in one embodiment of the present invention, to calibrate a flying height tester, the calibration standard 100 is placed in the flying height tester in place of the original glass disc (not shown) of the tester under the tester's light source 80. As shown in **Figures 3b** and **3c**, in calibrating the flying height tester, height measurements are taken by the tester, yielding 'observed' distances. The 'observed' distances are compared with the 'actual' distances at those locations. In one embodiment, a linear translator and computer (not shown) are utilized to position the standard 100 appropriately for measurement. In this embodiment, at each measurement point, monochromatic light 88a is directed at the (transparent) mock disc 10 by the light source 80, as shown in **Figure 3b**. The light 88a impinges the disc 10 at an angle incident θ to a first mock disc surface 12 and continues through the (glass) mock disc 10 along path 88b to a second mock disc surface 11, where it splits and is partially reflected. The

reflected portion follows path 88c through the disc 10 to the first surface 12, and follows path 88d to a sensor 90 of the flying height tester (not shown). The remaining light follows path 88e to the mock slider (head) surface 22 where it is reflected to the mock disc 10 via path 88f. The light impinges the second surface 11 of the mock disc 10, follows path 88g through the disc 10 and follows path 88h to the tester sensor 90. The slight angular deviations between paths at the air/disc interface are due to the Snell effect. Both the height h2 and the incident angle θ have been exaggerated in **Figure 3b** for illustrative purposes. Path 88a is actually substantially normal to the mock disc surface 12 with typical flying height testers.

[0018] **Figure 4** illustrates surface irregularity compensation and provides further detailed illustrations of two mock heads according to an embodiment of the present invention. As seen in **Figure 4a**, because of surface irregularities upon the top of each mock head 20, the distance, He, from disc to mock head surface 21 varies with position. In one embodiment of the present invention, the mock head's surface profile may be determined by a device such as a profilometer. This surface profile, combined with the knowledge of the 'actual' dimensions of the mock head 20 (by AFM, etc.) enable improved calibration. The true depth Ha of the recessed portion of the mock head 20 is slightly different than the apparent depth H1 (because of high points 402 on the mock head 20 surface). Utilizing Ha as the 'actual' distance provides a more accurate value. In an embodiment, the acquired surface irregularity information may be used by the flying height tester computer to provide a correction factor or a series of correction factors for the calibration.

[0019] **Figures 4b** and **4c** further illustrate a mock head slider 20 with a recessed surface 23 and inclined surface 22 (*see* **Figure 4b**) and a mock head slider 20 with a series of recessed surfaces (grooves) 23 at varying depths (*see* **Figure 4c**) under an embodiment of the present

invention. In one embodiment, recessed surface 23 length L1 is greater than 50 microns, and the recessed surface 23 depth (flying height) H1 is greater than 2 nanometers. In one embodiment, inclined surface height (rise) H2 is between 12 and 13 microinches (.31-.33 microns), and inclined surface 22 length (run) L2 approaches 100 mils (2,540 microns). As stated above, the mock heads 20 can be used together in a calibration standard 100 (*see* **Figure 3a**), or they can be used alone in a calibration standard 100.

[0020] **Figure 5** provides a graphical illustration of the 'unique fit' solution utilized for providing a continuous spectrum of uniquely-valued combinations associatable to a range of head/disc gaps under principles of an embodiment of the present invention. In one embodiment, light of multiple wavelengths (*e.g.*, three wavelengths 501,502,503) is directed at the surface to be measured. In one embodiment, upon varying the distance between the mock head and mock disc to obtain the maximum and minimum light intensity (for light intensity calibration), multiple curves may be developed. After calibrating light intensity at the different wavelengths (equalizing amplitude), the wavelengths displayed superimposed provide multiple curves that may be utilized for a 'unique fit' solution spectrum. By optical interference, light intensity 524 received by the detector oscillates repeatedly between the maximum 526 and the minimum 528 as the distance measured increases (or decreases). Although each curve passes through the same light intensity values multiple times as the measured distance increases (or decreases) through the range of possible values, the combination of values 511,512,513 provided by the multiple-wavelength light source is unique for each distance in the range of possible distances 522. This 'unique fit' solution provides a range of light intensity combinations that is directly and uniquely associatable to the range of possible distances to be measured.

[0021] According to embodiments of the present invention, a calibration device is provided for both light intensity / unique fit theory curves (inclined surface; *See*, *e.g.*, **Figure 4b**) and for specific depth (flying height) measurement calibration (recessed surface; *See*, *e.g.*, **Figure 4c**). In this embodiment, both mock heads are provided in the same calibration standard (as opposed to requiring a separate standard/device). As stated previously, typical calibration standards in the art provide no more than a series of grooves for gap calibration (on the disc side, not on the head side). For light intensity calibration and the development of theory curves, a separate component (a wedge piece) would need to be added, adding cost to the manufacture and operation. Therefore, in addition to the advantages of having varying-depth grooves on the mock head (as opposed to on the mock disc; as explained above), having all parts integrated in a single calibration standard is advantageous from both a complexity and a cost standpoint. Further, the process of forming grooves (by, *e.g.*, ion milling or chemical etching) in a mock disk of glass, for example, is more difficult because of its hardness than forming similar grooves in a mock head (substrate). Further, etching glass with such methods produces surface roughness (irregularities) as large as 0.4 microinches (~10 nanometers) or more, exacerbating calibration difficulties.

[0022] Further, employing optical interference techniques with calibration grooves 60 formed in the mock disc 44, such as in the prior art (*see* **Figure 2a**), causes significant inaccuracies. If a measurement location is too close to the edge of a ridge 64, one or more of the light beam's return paths may pass through the air 212 (glass-air-glass, rather than just glass), altering the path of the light (*see* **Figure 2c**). Because the distance in which one of the light beam travels through air defines the height measurement perceived, the light should travel through consistent paths through the glass (*i.e.*, uniform thickness mock disc, such as the present invention).

[0023] **Figure 6** provides an illustration of a mock head design according to an alternative embodiment of the present invention. In this embodiment, the mock head 20 has two separate inclined surfaces 22,24. In this embodiment they can be formed with differing slopes (H2/L2 and H4/L4). An inclined surface 22,24 with a shallow slope could be used for fine adjustment calibration and an inclined surface 22,24 with a steeper slope could be used for large range adjustment.

[0024] **Figure 7** provides illustrations of three mock head designs according to alternative embodiments of the present invention. As shown in **Figure 7a**, in one embodiment, the mock head 20 has a cylindrically convex (curved) portion 702 and a recessed surface portion 704. In this embodiment, the cylindrical portion 702 is used for light intensity calibration and gap spectrum calibration (via light intensity curves, as explained above). In this embodiment, the dimensions of the cylindrical portion 702 may be determined by AFM and known geometric principles to yield 'actual' (flying height) distances H 706 (similar to inclined surface 22; *see* **Figure 3b**). Similar to above, in this embodiment, the recessed portion 704 is utilized for specific flying height calibration. As illustrated in **Figure 7b**, in another embodiment, a mock head 20 with a cylindrical portion 702 is utilized in the calibration standard. In this embodiment, the cylindrical portion 702 is used for light intensity calibration, gap spectrum calibration (via light intensity curves), and specific flying height calibration. In this embodiment, specific gap measurement calibration (via 'actual' vs. 'measured' differential) is taken at a desired location. As stated the 'actual' distance is known by a device such as an AFM. In another embodiment, the curved surface 702 of the designs shown in **Figure 7a** and **7b** is a spherical (convex) surface. In an alternative embodiment, as shown in **Figure 7c**, a curved surface 702 (*e.g.*, spherical,

cylindrical, etc.) occupies the top portion of a mock head 20 with an inclined surface portion, providing further flexibility of calibration.

[0025] Although several embodiments are specifically illustrated and described herein, it will be appreciated that modifications and variations of the present invention are covered by the above teachings and within the purview of the appended claims without departing from the spirit and intended scope of the invention.